Supplementary Material

Supplement TableS1. Univariate and Multivariate analysis of prognostic factors for DFS.

Variables	DFS					
	Univariate analysis			Multivariate analysis		
	HR	95%CI	p value	HR	95%CI	p value
Gender (Female)	0.575	0.287-1.150	0.117			
Age (≥60), years	1.025	0.660-1.592	0.911			
APRI (>0.5)	1.535	0.992-2.374	0.054			
FIB-4 (Positive)	1.063	0.615-1.838	0.826			
AFP (>200), ng/mL	0.737	0.440-1.235	0.247			
MVI (Present)	2.110	1.336-3.333	0.00136	1.728	1.078-2.768	0.0230
Grade (G2-3)	1.106	0.639-1.913	0.718			
Size (>5), cm	1.888	1.218-2.926	0.00449	2.254	1.348-3.770	0.00195
Number (Multiple)	2.244	1.230-4.093	0.00842	3.539	1.078-2.768	<0.001

AFP, alpha fetoprotein; APRI, AST to Platelet ratio index; FIB-4, Fibrosis-4 Index; MVI: microvascular invasion;

Supplement TableS2. Univariate and Multivariate analysis of TILs features for DFS.

Variables	DFS					
	Univariate analysis			Multivariate analysis		
	HR	95%CI	p value	HR	95%CI	p value
TIL Aggregation	0.258	0.114-0.583	0.00111	0.021	0.074-0.811	0.0212
TIL Fraction	0.105	0.014-0.781	0.0277	1.186	0.068-20.549	0.907

TIL Aggregation: The density of TILs calculated using a k-nearest neighbor algorithm based on the 50 nearest like-class neighbors.

Supplement TableS3. Univariate of Collagen feature for DFS.

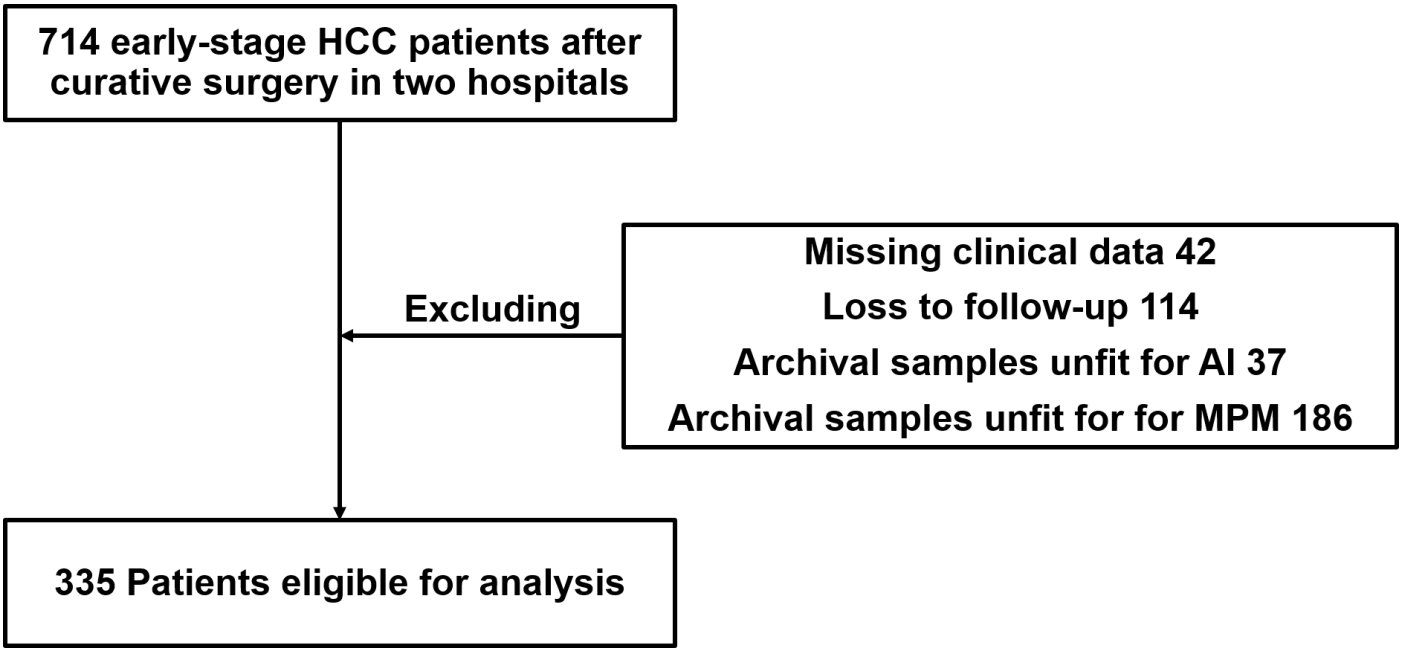
Variables	DFS		
	Univariate analysis		
	HR	95%CI	p value
CF Fraction	2.192	0.148-32.502	0.568
CF Density	3.410	0.212-54.761	0.386
CF Length	1.152	0.798-1.663	0.450
CF Width	3.003	0.273-33.098	0.369
CF Straightness	2.047	0.541-7.741	0.291
Cross-link Density	1.449	0.818-2.567	0.203
Cross-link Spacing	1.016	0.978-1.054	0.421
CF Orientation	4.643	1.057-20.401	0.042

CF：Collagen Fiber

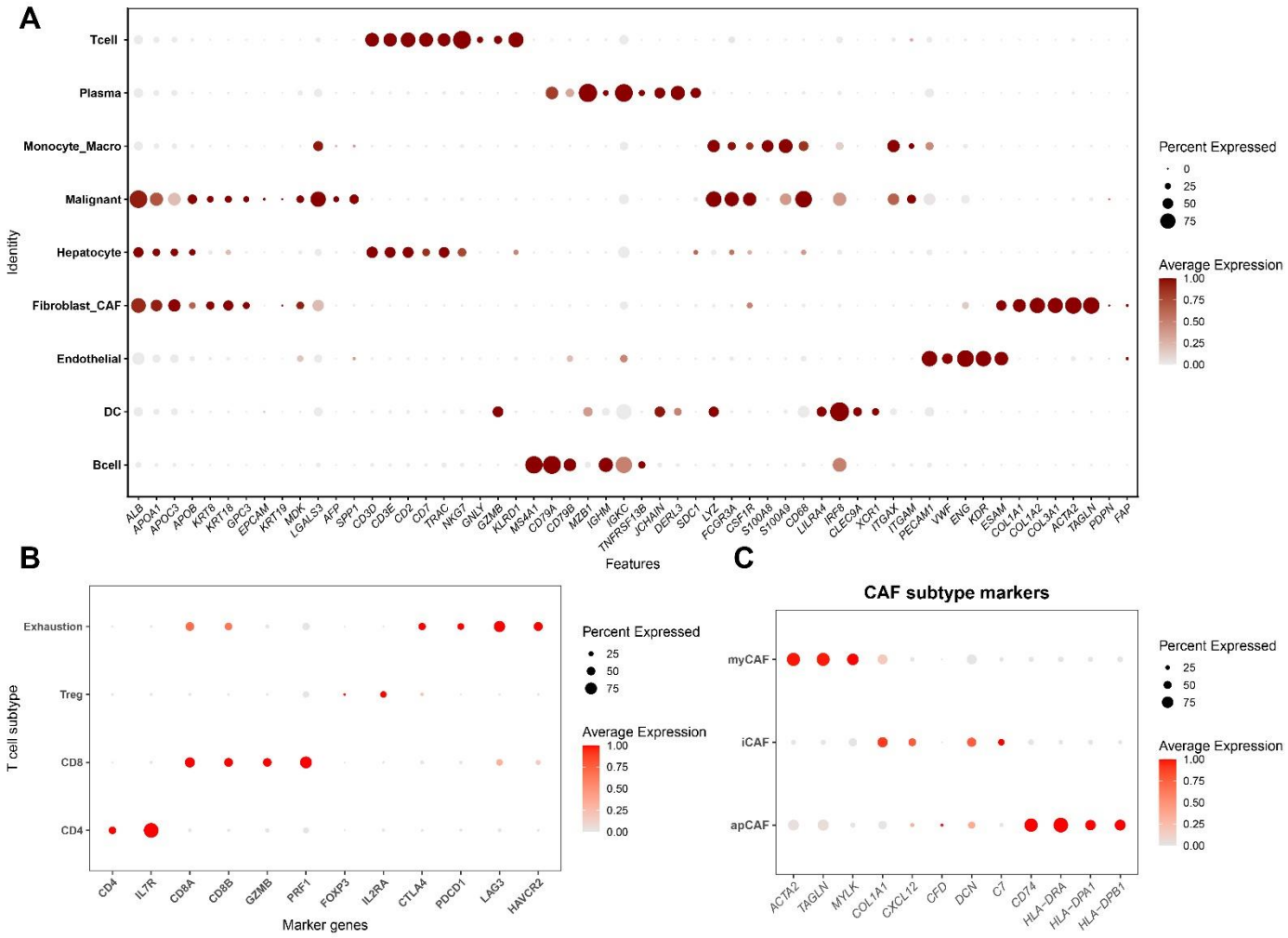
Supplement TableS4. Multivariate for DFS.

Variables	DFS		
	Multivariate analysis		
	HR	95%CI	p value
Size (>5cm)	2.196	1.280-3.768	0.004
Number (multiple)	2.310	1.113-4.794	0.025
MVI (present)	1.981	1.226-3.200	0.005
TIL Aggregation (high)	0.495	0.311-0.788	0.003
Orientation Anisotropy (high)	3.574	2.128-6.003	<0.004

TIL Aggregation: The density of TILs calculated using a k-nearest neighbor algorithm based on the 50 nearest like-class neighbors.

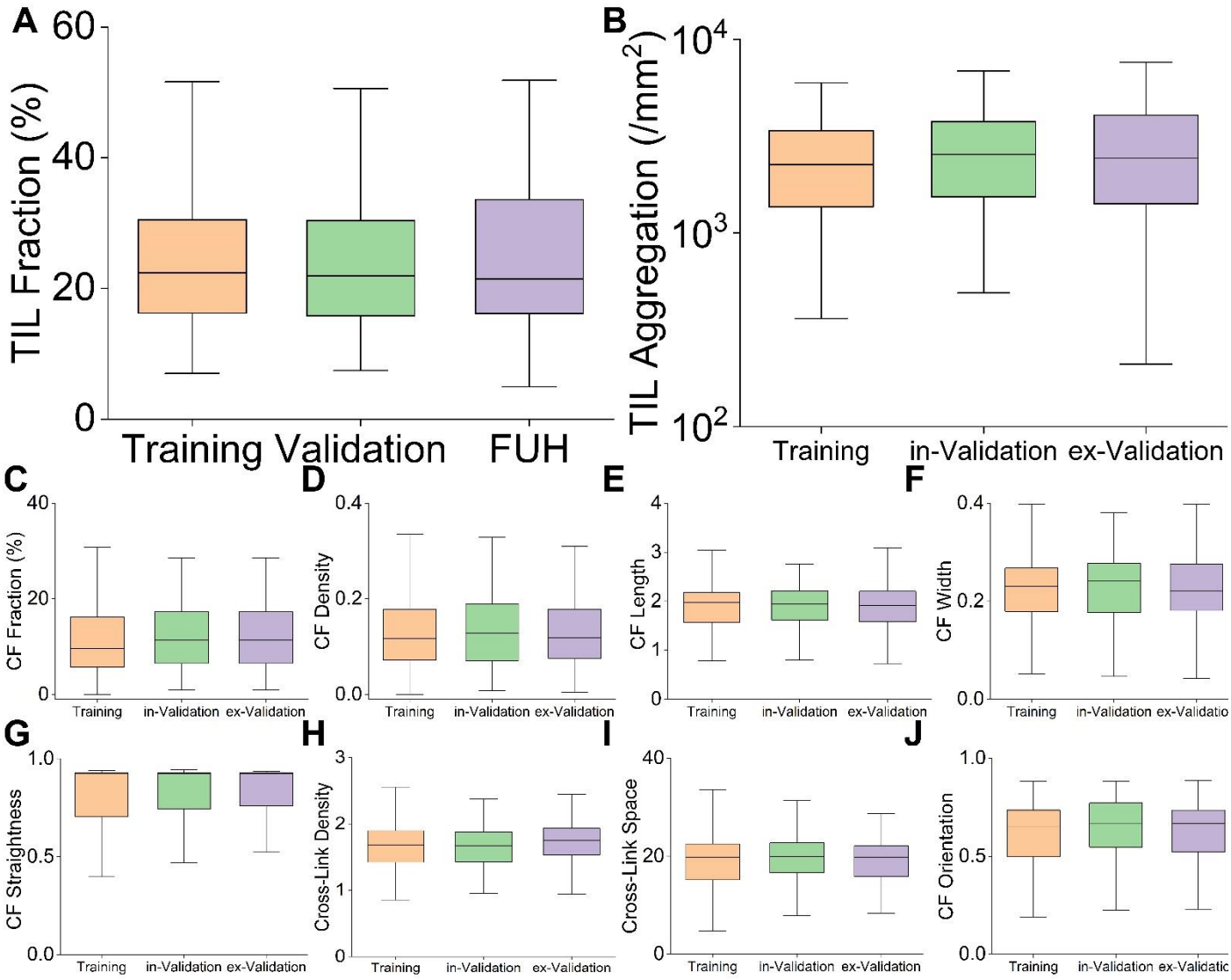


Supplement FigS1. Patient flowchart



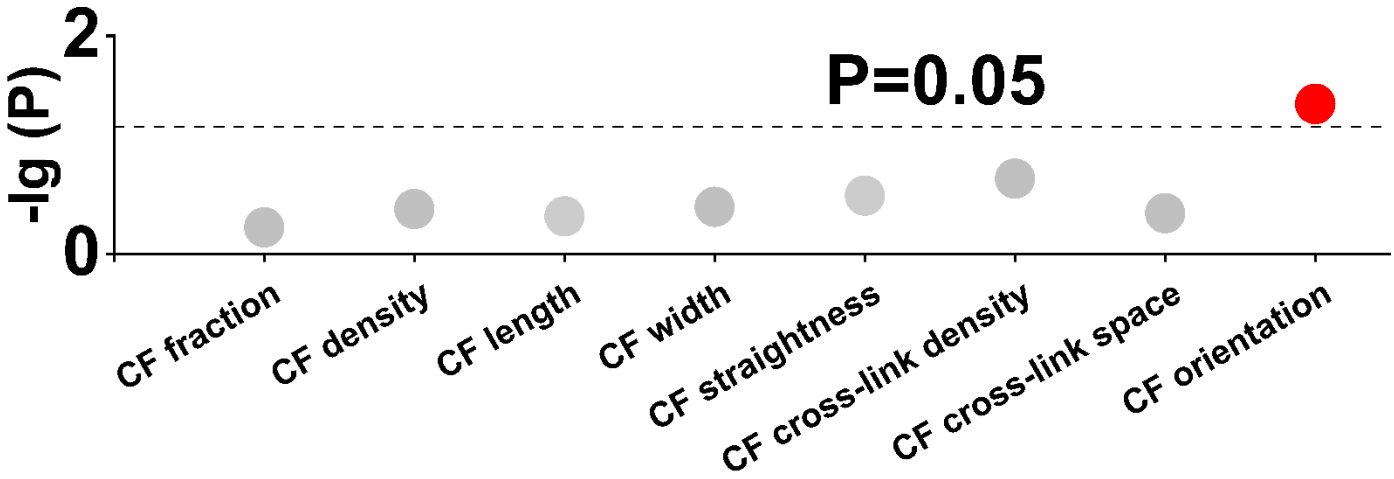
Supplement FigS2. Analysis of major cell populations and characteristic marker expression in the tumor microenvironment.

A. Marker gene expression across major cell populations in the tumor microenvironment. **B.** Marker gene expression patterns of T-cell subtypes. **C.** Marker gene expression patterns of CAF subtypes. Dot size indicates the percentage of expressing cells, and color intensity represents average expression levels.

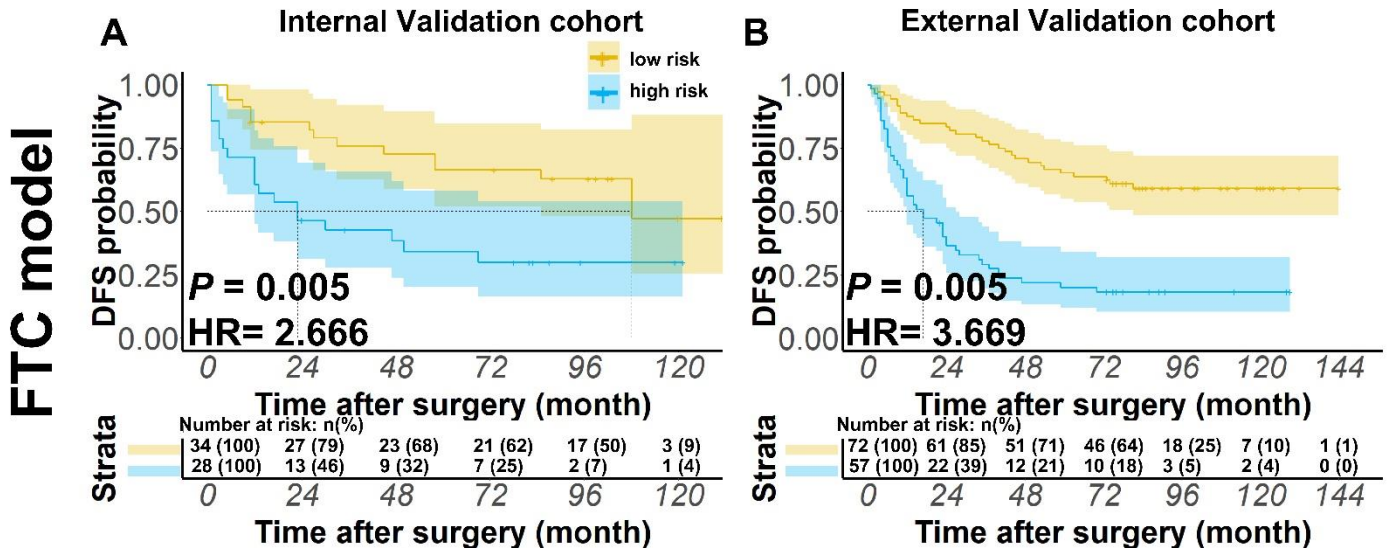


Supplement FigS3. Distribution of TILs Features and CF features performance

A. TILs Fraction **B.** TILs Density **C.** CF Fraction **D.** CF Density, **E.** CF Length, **F.** CF Width, **G.** CF Straightness, **H.** Cross-Link Density, **I.** Cross-Link Spacing, **J.** CF Orientation.

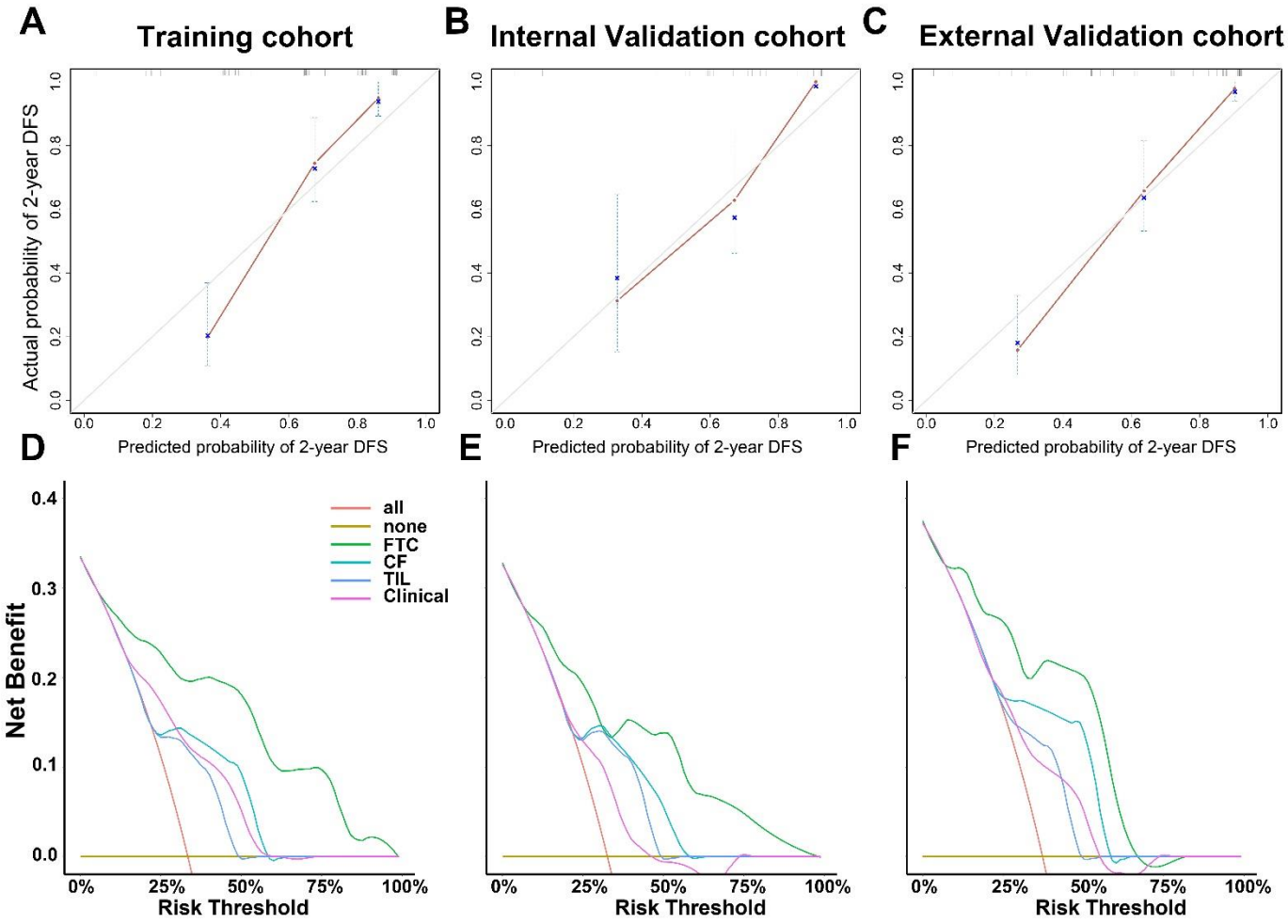


Supplement FigS4. The p-values of the eight collagen features in Cox regression analysis.



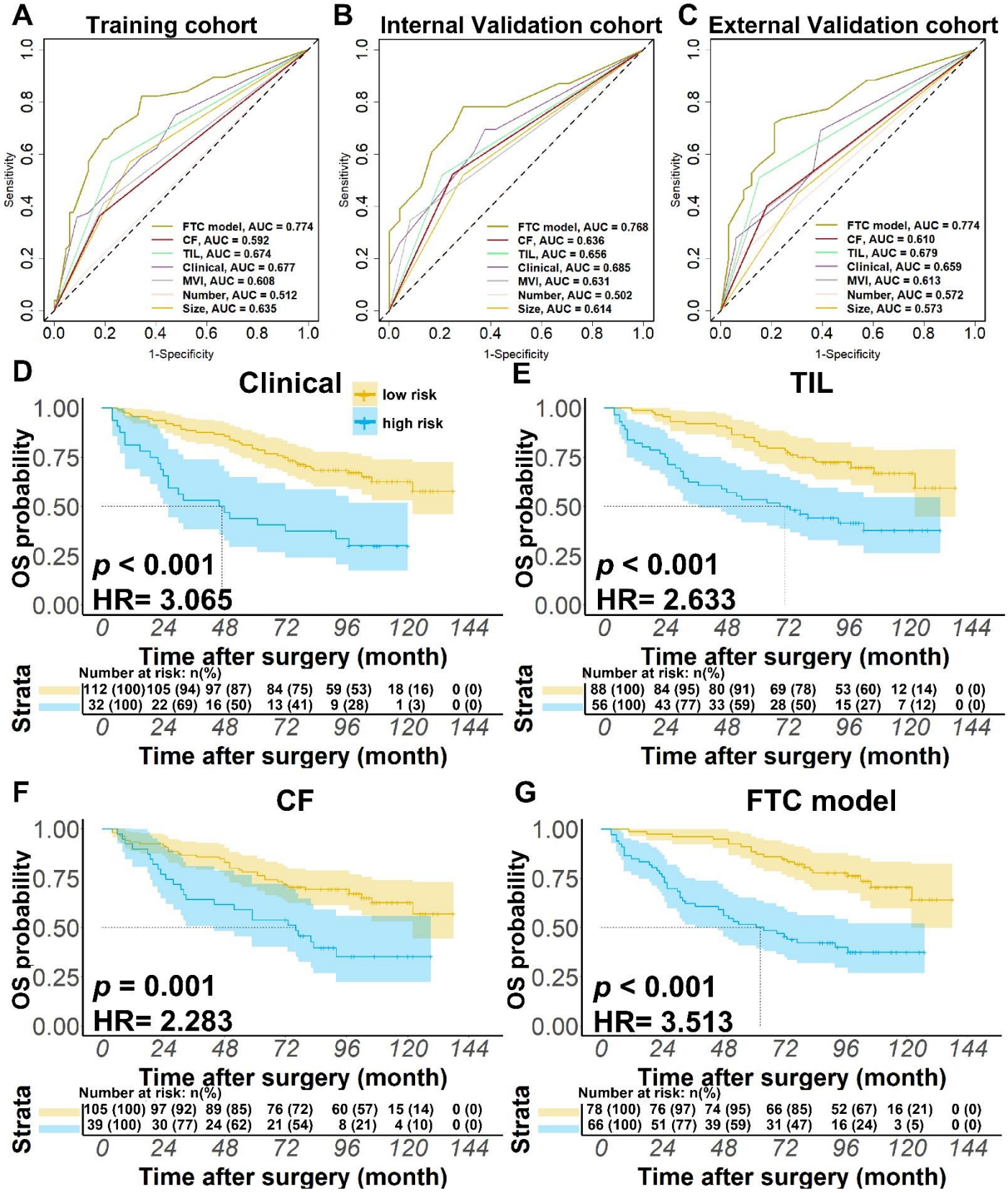
Supplement FigS5. The FTC model effectively distinguishes high- and low-risk populations in both internal and external validation.

A Performance assessment of models in terms of Kaplan-Meier survival based on the low-risk and high-risk groups by FTC model in internal and external validation cohorts.



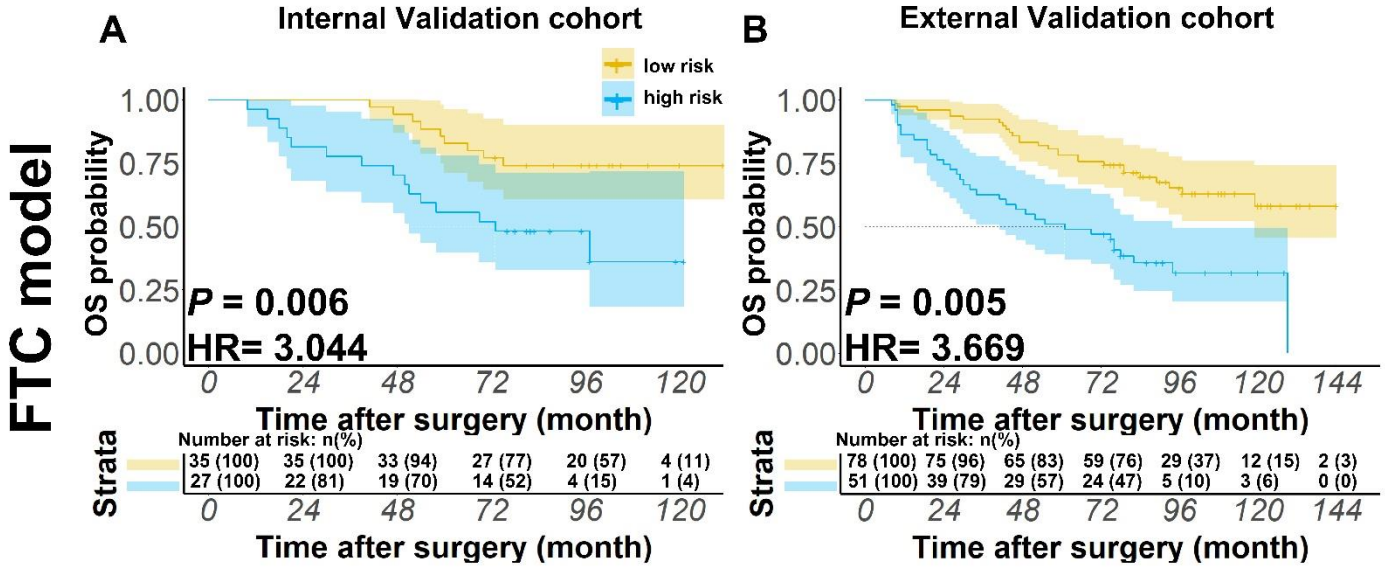
Supplement FigS6. Calibration curves and clinical decision curves (DCA) for predicting recurrence outcomes

ABC. Calibration curves for the FTC model on the training cohort, internal validation cohort and external validation cohort. **DCE.** DCA demonstrating the net benefit of three models across various threshold probabilities for three cohorts.



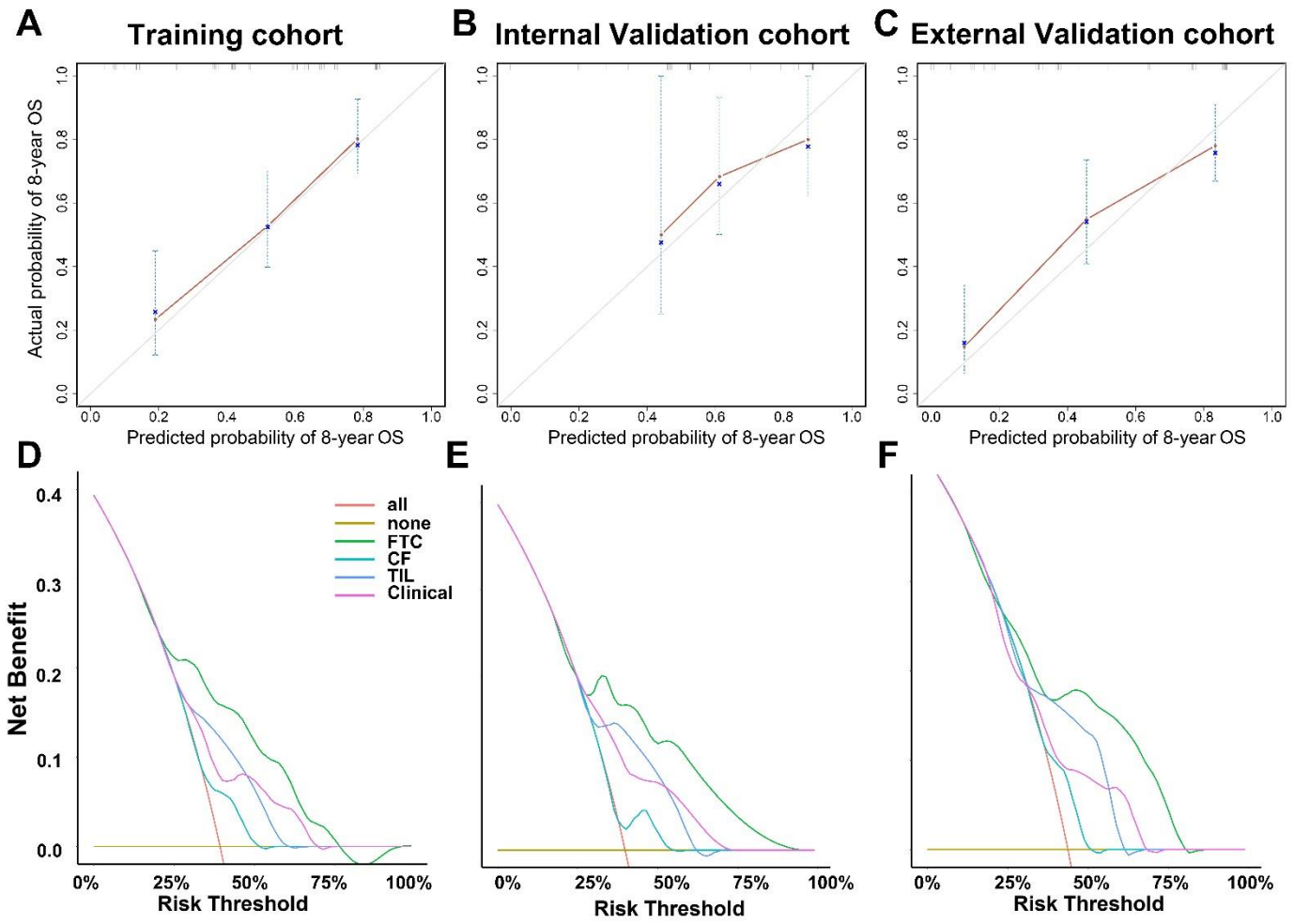
Supplement FigS7. FTC-model Effectively Predicts 8-Year OS Outcomes

ABC. Performance assessment of models in terms of Area Under the Curve (AUC) analyses for overall survival (OS) in three cohort. **DEFG.** Performance assessment of models in terms of Kaplan-Meier survival based on the low-risk and high-risk groups by four model in the training cohort.



Supplement FigS8. The FTC model effectively distinguishes high- and low-risk populations in both internal and external validation.

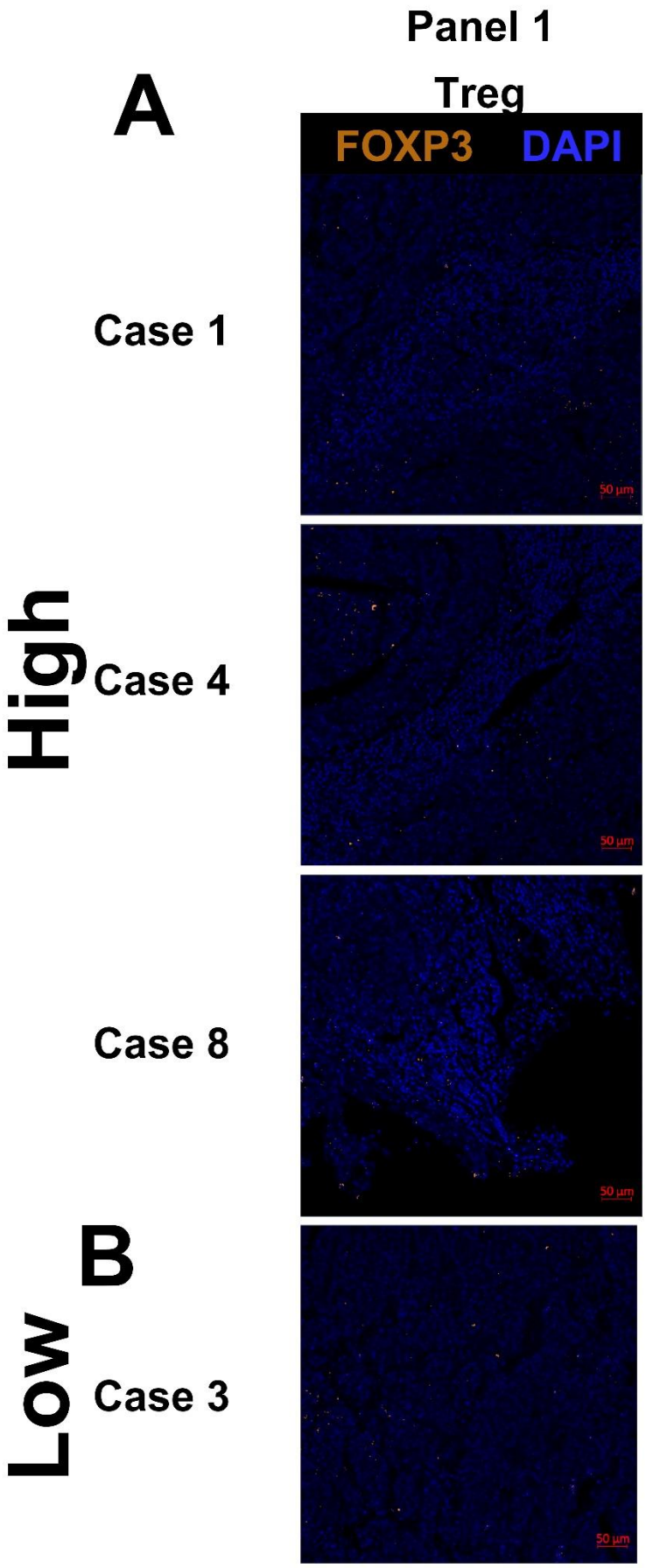
A Performance assessment of models in terms of Kaplan-Meier survival based on the low-risk and high-risk groups by FTC model in internal and external validation cohorts.



Supplement FigS9. Calibration curves and clinical decision curves (DCA) for predicting survival outcomes

ABC. Calibration curves for the FTC model on the training cohort, in-validation cohort and ex-validation cohort.

DCE. DCA demonstrating the net benefit of three models across various threshold probabilities for three cohorts.



Supplement FigS10. Correlation Between CAFs and Treg

Representative images showing Treg (FOPX3, deep yellow). A. Regions of high CAF expression. B. Regions of low CAF expression.